Status of the JUNO experiment

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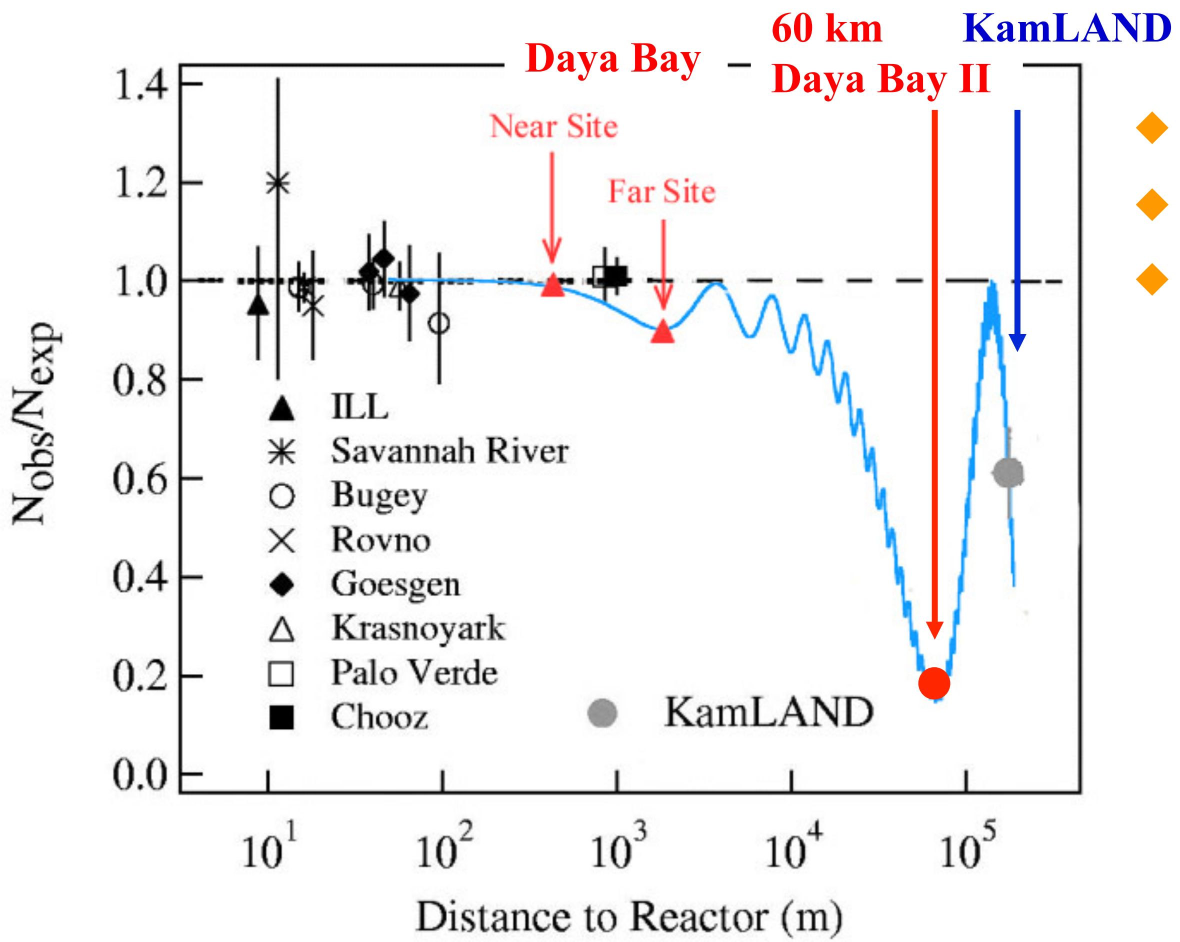
Institute of High Energy Physics
Clermont-Ferrand, April 9, 2014

The JUNO Experiment

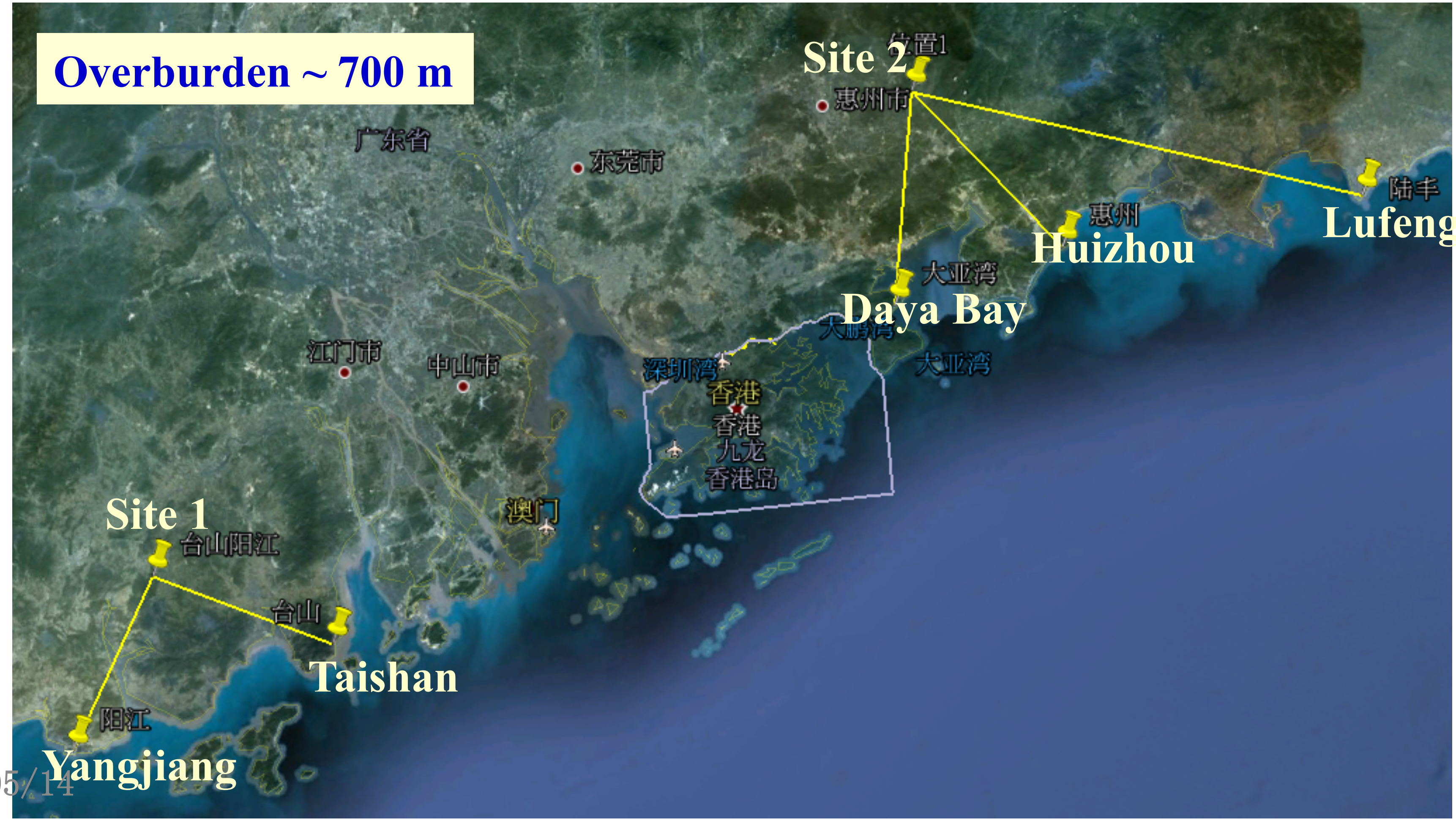


- 20 kton LS detector
- 3% energy resolution
- Rich physics possibilities
  - Mass hierarchy
  - Precision measurement of 4 mixing parameters
  - Supernovae neutrinos
  - Geoneutrinos
  - Sterile neutrinos
  - Atmospheric neutrinos
  - Exotic searches

Talk by Y.F. Wang at ICFA seminar 2008, Neutel 2011; by J. Cao at Nutel 2009, NuTurn 2012 ;
Paper by L. Zhan, Y.F. Wang, J. Cao, L.J. Wen, PRD78:111103,2008; PRD79:073007,2009

The Site

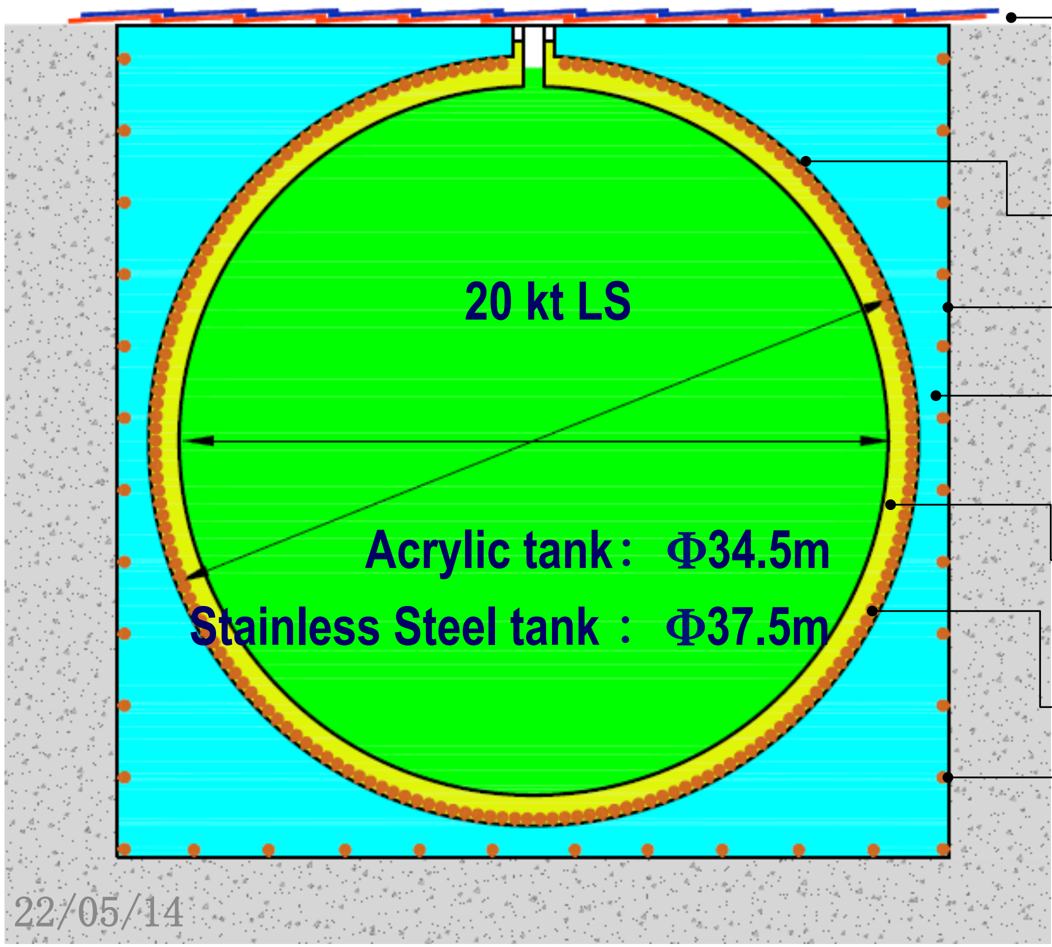
	Daya Bay	Huizhou	Lufeng	Yangjiang	Taishan
Status	Operational	Planned	Planned	Under construction	Under construction
Power	17.4 GW	17.4 GW	17.4 GW	17.4 GW	18.4 GW，9.2 by 2020



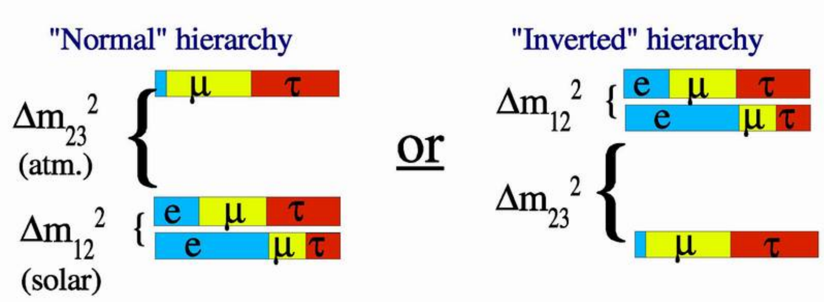
The plan: a large LS detector

- LS volume: × 20➔ for more mass & statistics
- light(PE) × 5➔ for resolution

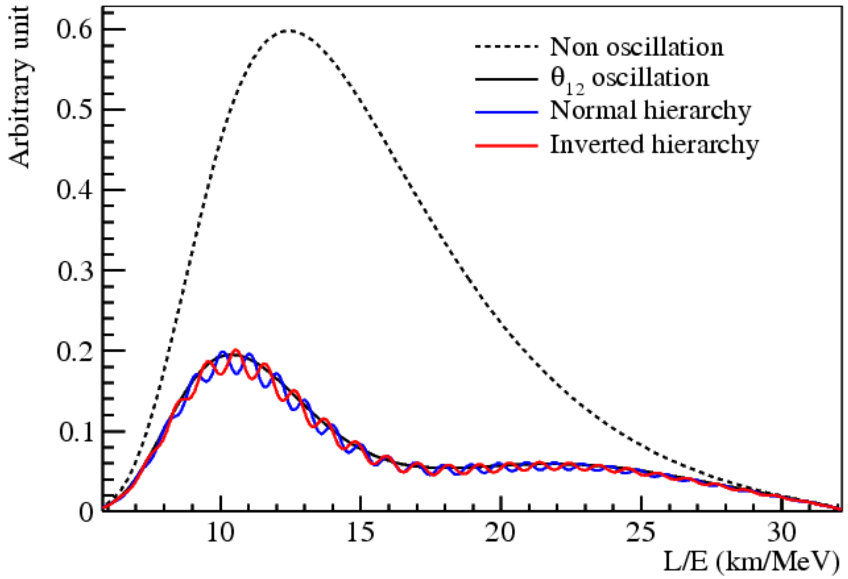
40 events/day

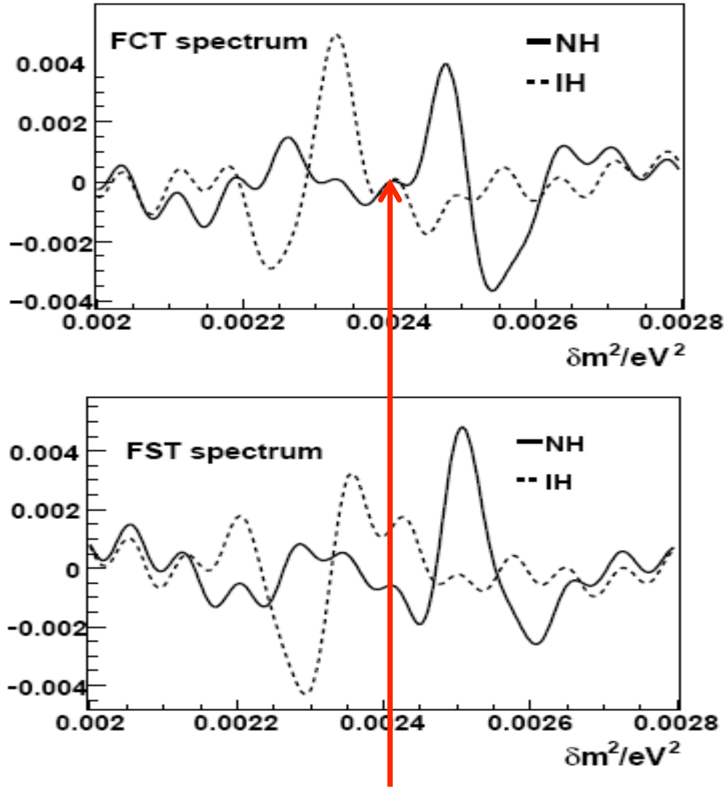


Mass Hierarchy at Reactors



$$\Delta m_{31}^2 = \Delta m_{32}^2 + \Delta m_{21}^2$$
$$\mathrm{NH}: \; |\Delta m_{31}^2| = |\Delta m_{32}^2| + |\Delta m_{21}^2|$$
$$\mathrm{IH}: \; |\Delta m_{31}^2| = |\Delta m_{32}^2| - |\Delta m_{21}^2|$$





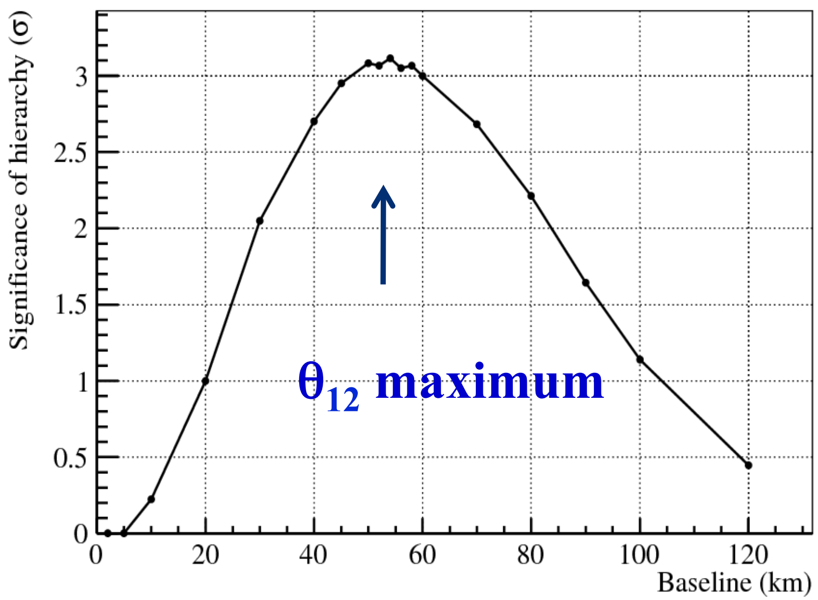
ΔM^2_{23}

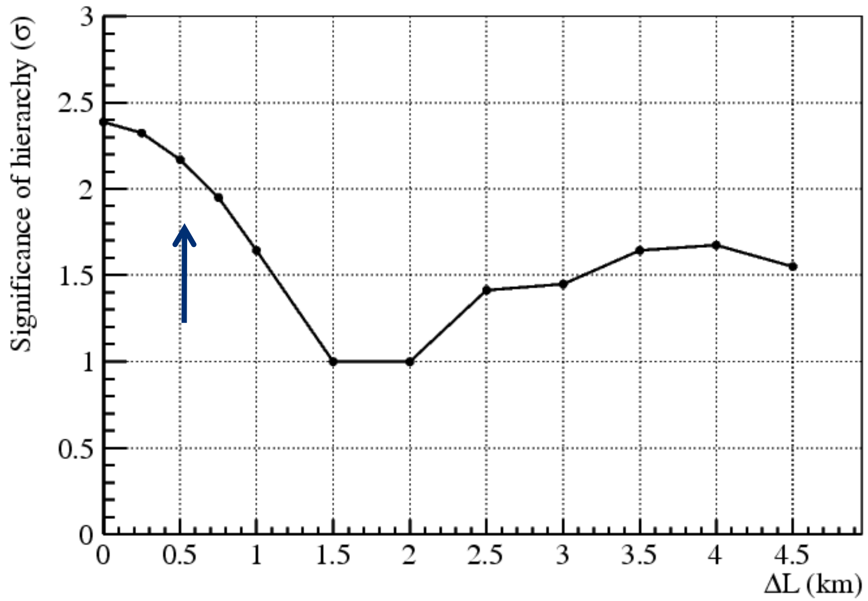
$$P_{ee}(L/E) = 1 - P_{21} - P_{31} - P_{32}$$
$$P_{21} = \cos^4(\theta_{13}) \sin^2(2\theta_{12}) \sin^2(\Delta_{21})$$
$$P_{31} = \cos^2(\theta_{12}) \sin^2(2\theta_{13}) \sin^2(\Delta_{31})$$
$$P_{32} = \sin^2(\theta_{12}) \sin^2(2\theta_{13}) \sin^2(\Delta_{32})$$

L. Zhan et al., PRD78:111103,2008; PRD79:073007,2009

Optimum baseline

- **Optimum at the oscillation maximum of θ_{12}**
- **Multiple reactors may cancel the oscillation structure**
  - ⇨ **Baseline difference cannot be more than 500 m**





Energy scale can be self-calibrated

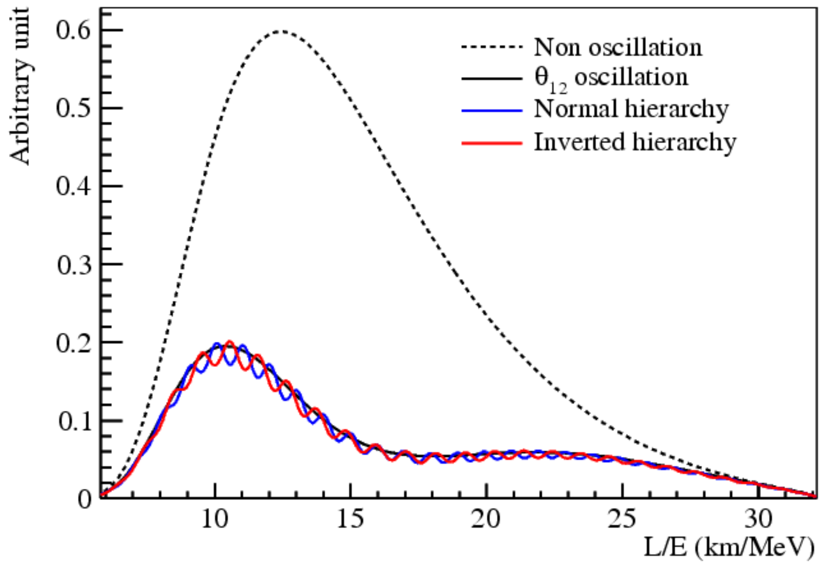
If we have a residual non-linearity:

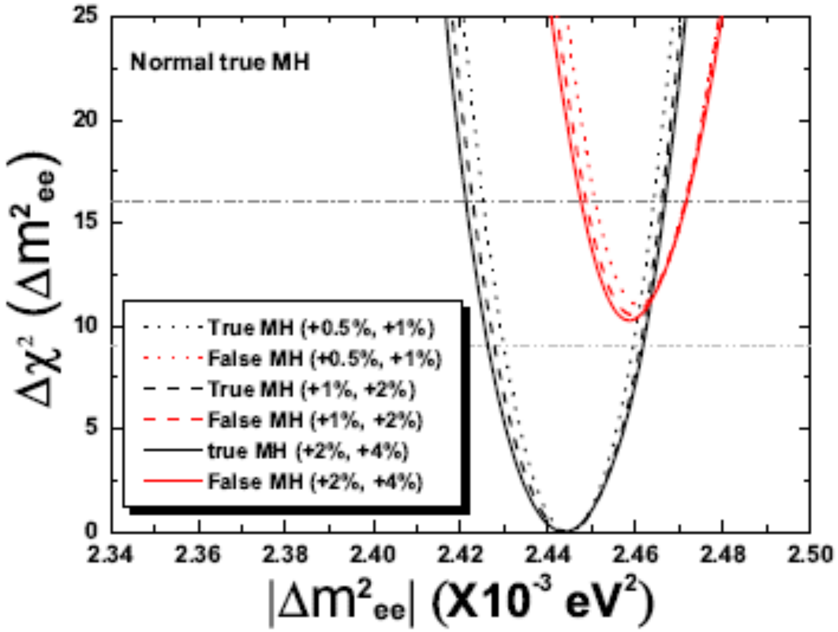
$$\frac{E_{\rm rec}}{E_{\rm true}} \simeq 1 + q_0 + q_1 E_{\rm true} + q_2 E_{\rm true}^2 \,,$$

by introduce a self-calibration(based on ΔM^2_{ee} peaks):

$$\chi^2_{\rm NL} = \sum_{i=0}^{2} q_i^2/(\delta q_i)^2$$

effects can be corrected and sensitivity is un-affected





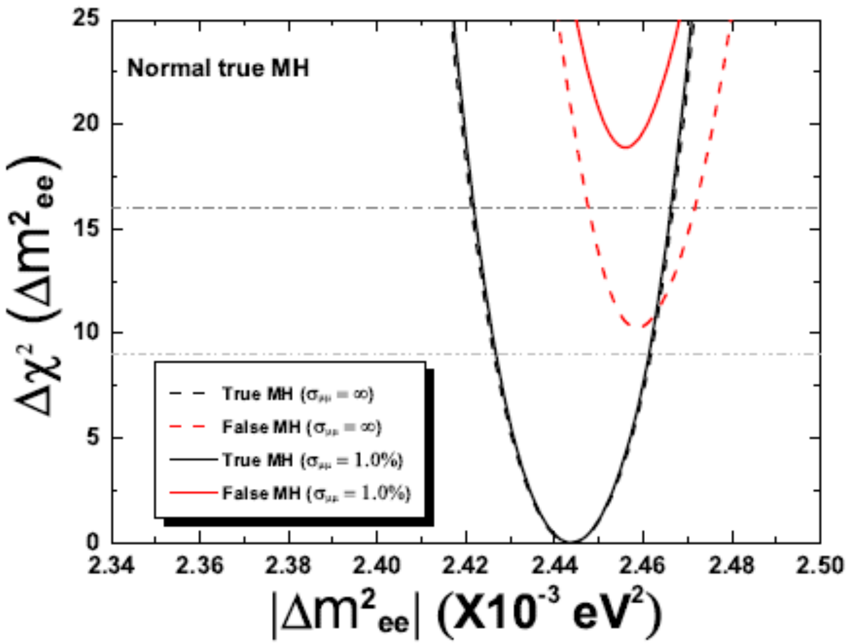
Physics Reach

Thanks to a large θ_{13}

For 6 years,

- ◆ Ideally, The relative measurement can reach a sensitivity of 4σ, while the absolute measurement (with the help of $\Delta m^2_{\mu\mu}$ ~ 1%) can reach 5σ
- ◆ Due to reactor core distributions, relative measurement can reach a sensitivity of 3σ, while the absolute measurement can reach 4σ

Detector size: 20kt
Energy resolution: 3%/√E
Thermal power: 36 GW



Y.F. Li et al., arXiv:1303.6733

Precision measurement of mixing parameters

- **Fundamental to the Standard Model and beyond**
- **Probing the unitarity of U_{PMNS} to ~1% level !**
  - ⇨ **Uncertainty from other oscillation parameters and systematic errors, mainly energy scale, are included**

	Current	Daya Bay II
Δm^2_{12}	3%	0.6%
Δm^2_{23}	5%	0.6%
$\sin^2\theta_{12}$	6%	0.7%
$\sin^2\theta_{23}$	20%	N/A
$\sin^2\theta_{13}$	14% ➔ 4%	~ 15%

Will be more precise than CKM matrix elements !

Supernova neutrinos

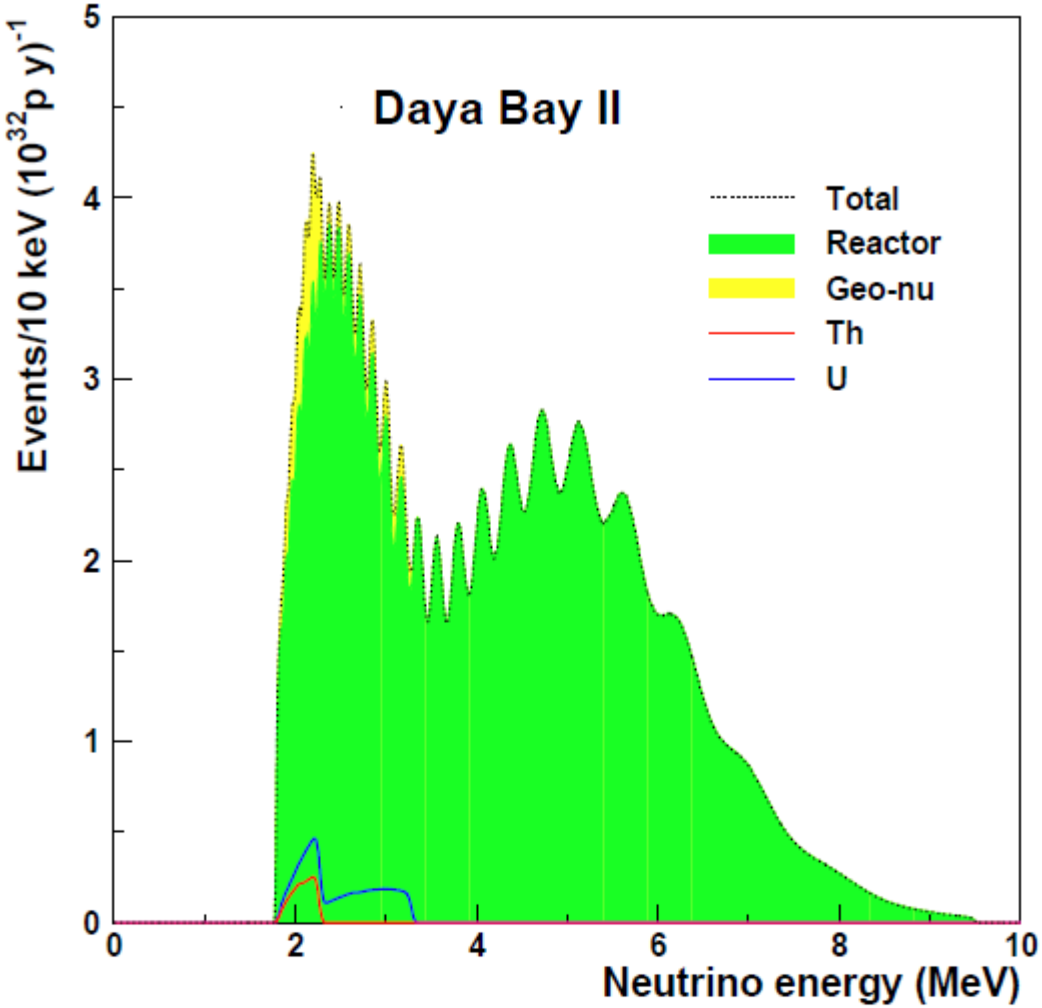
- **Less than 20 events observed so far**
- **Assumptions:**
  - **Distance: 10 kpc (our Galaxy center)**
  - **Energy: 3×10^{53} erg**
  - **L_ν the same for all types**
  - **Tem. & energy**
    - $T(\underline{\nu}_e) = 3.5$ MeV, $<E(\underline{\nu}_e)> = 11$ MeV
    - $T(\nu_e) = 5$ MeV, $<E(\nu_e)> = 16$ MeV
    - $T(\nu_x) = 8$ MeV, $<E(\nu_x)> = 25$ MeV
- **Many types of events:**
  - $\bar{\nu}_e + p \rightarrow n + e^+$, ~ 3000 correlated events
  - $\bar{\nu}_e + {}^{12}C \rightarrow {}^{12}B^* + e^+$, ~ 10-100 correlated events
  - $\nu_e + {}^{12}C \rightarrow {}^{12}N^* + e^-$, ~ 10-100 correlated events
  - $\nu_x + {}^{12}C \rightarrow \nu_x + {}^{12}C^*$, ~ 600 correlated events
  - $\nu_x + p \rightarrow \nu_x + p$, single events
  - $\nu_e + e^- \rightarrow \nu_e + e^-$, single events
  - $\nu_x + e^- \rightarrow \nu_x + e^-$, single events

Water Cerenkov detectors can not see these correlated events

Energy spectra & fluxes of all types of neutrinos

Geoneutrinos

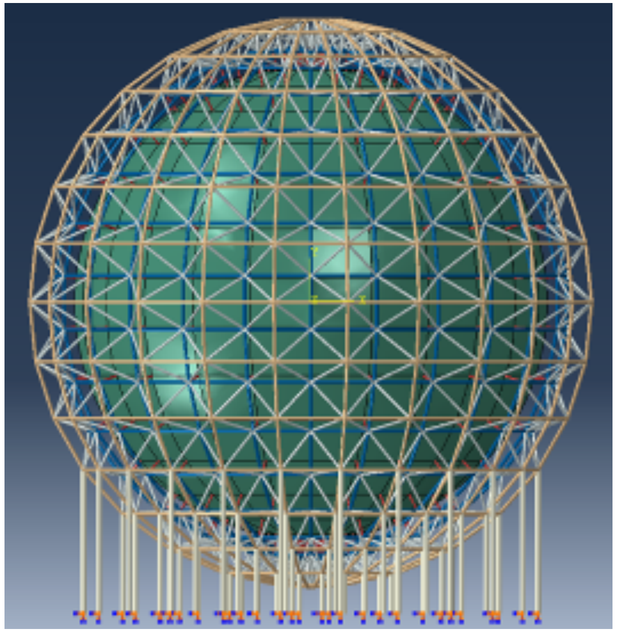
- **Current results:**
  - **KamLAND:** **40.0±10.5±11.5 TNU**
  - **Borexino:** **64±25±2 TNU**
- **Desire to reach an error of 3 TNU: statistically dominant**
- **Daya Bay II: >×10 statistics, but difficult on systematics**
- **Background to reactor neutrinos**

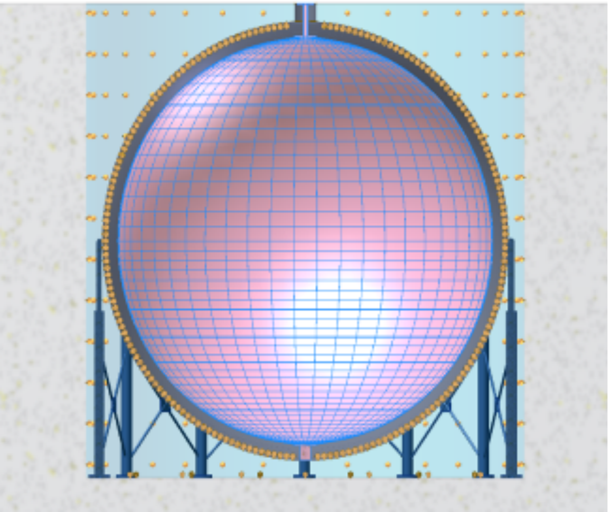


From Stephen Dye

Central Detector

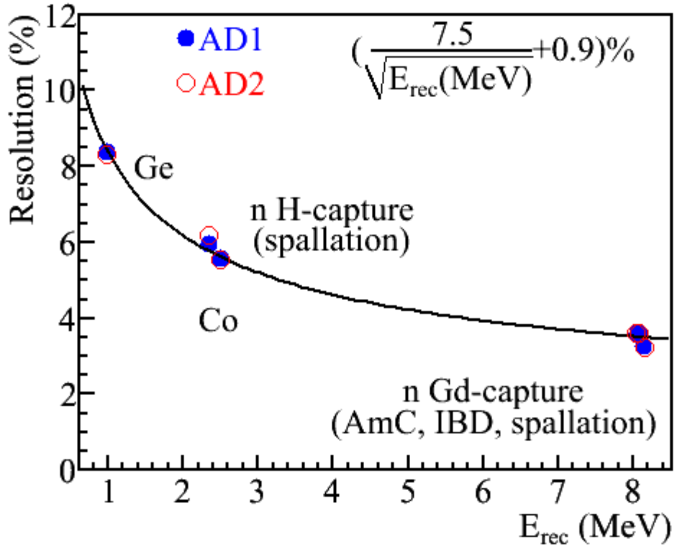
- **Some basic numbers:**
  - 20 kt liquid scintillator as the target
  - Signal event rate: 40/day
  - Backgrounds with 700 m overburden:
    - ✓ Accidentals(~10%), ^{9}Li/^{8}He(<1%), fast neutros(<1%)
- **A huge detector in a water pool:**
  - Default option: acrylic tank(D~35m) + SS structure
  - Backup option: SS tank(D~38m) + acrylic structure + balloon
- **Issues:**
  - Engineering: mechanics, safety, lifetime, …
  - Physics: cleanness, light collection, …
  - Assembly & installation
- **Design & prototyping underway**

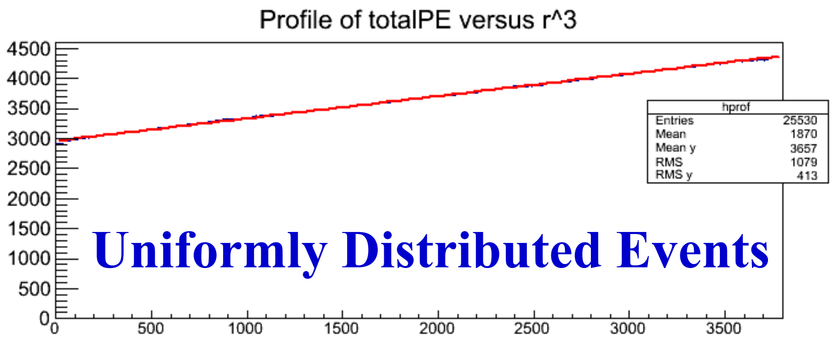


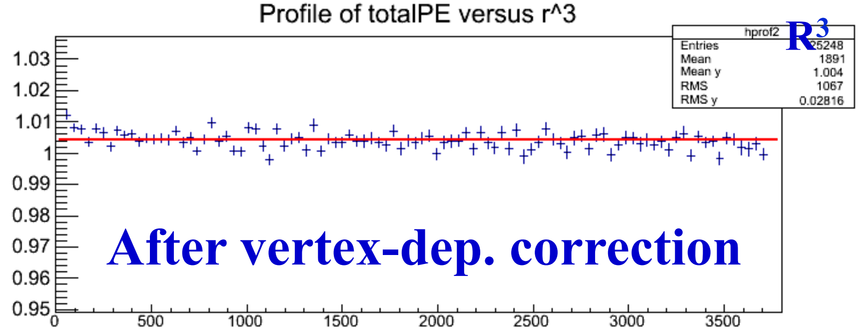


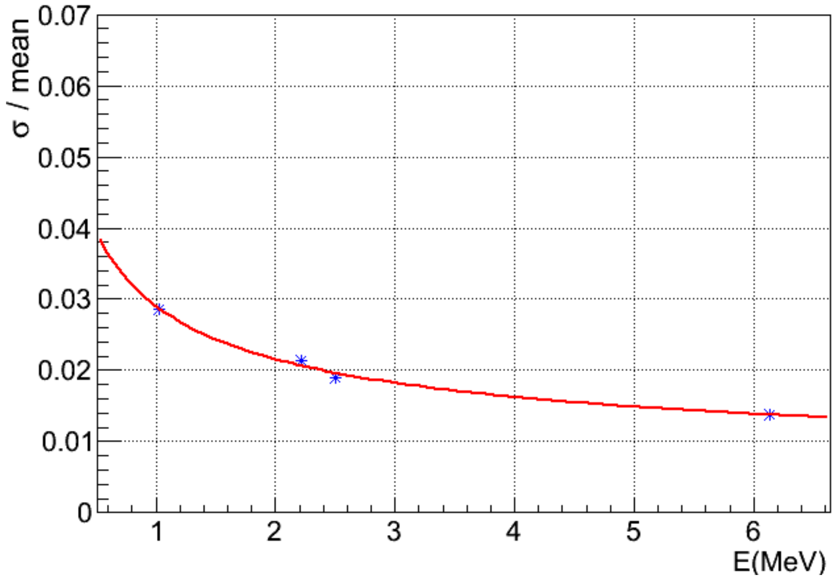
MC example：Energy Resolution

- **Based on DYB MC (tuned to data), except**
  - ⇨ **JUNO Geometry and 80% photocathode coverage**
  - ⇨ **PMT QE from 25% -> 35%**
  - ⇨ **Attenuation length (1m-tube measurement@430nm)**
    - ✓ **from 15m = abs. 30 m + Raylay scatt. 30 m**
    - ✓ **to 20 m = abs. 60 m + Raylay scatt. 30m**





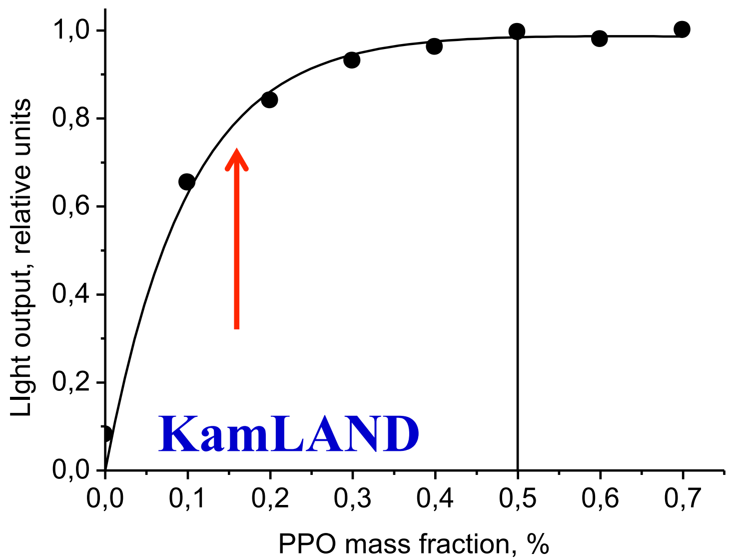




$3.0\%/\sqrt{E}$, or $(2.6/\sqrt{E}+0.3)\%$

Liquid Scintillator

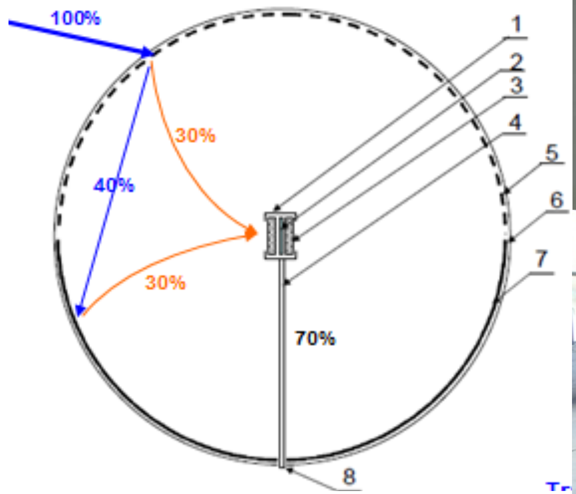
- **Requirements:**
  - ⇨ Low background: ➔ No Gd-loading
  - ⇨ Long attenuation length: 15m ➔ 30m
    - ✓ Improve raw materials
    - ✓ Improve the production process
    - ✓ Purification
  - ⇨ High light yield: optimize fluor concentration
- **Current Choice: LAB+PPO+BisMSB**

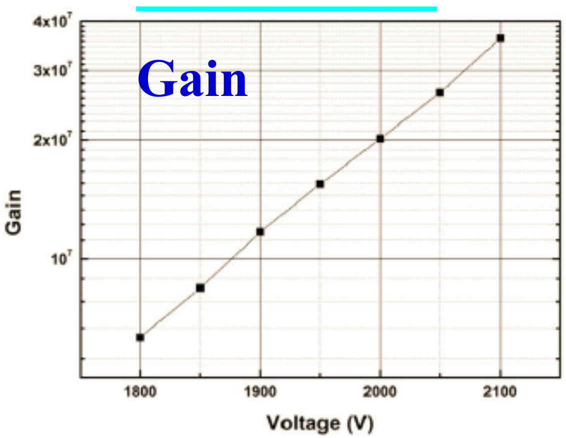


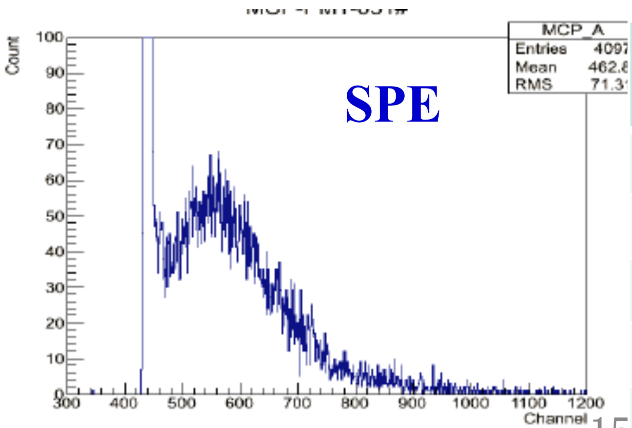
Linear Alky Benzene	Atte. L(m) @ 430 nm
RAW	14.2
Vacuum distillation	19.5
SiO_2 coloum	18.6
Al_2O_3 coloum	22.3
LAB from Nanjing, Raw	20
Al_2O_3 coloum, fourth time	27
Al_2O_3 coloum, second time	25
Al_2O_3 coloum, 8^{th} time	24

High QE PMT

- Two types of high QE 20” PMTs under development:
  - ⇨ Hammamatzu R5912-100 with SBA photocathode
  - ⇨ A new design using MCP: 4π collection
- MCP-PMT development:
  - ⇨ Technical issues mostly resolved
  - ⇨ Successful 8” prototypes
  - ⇨ 20” prototypes done



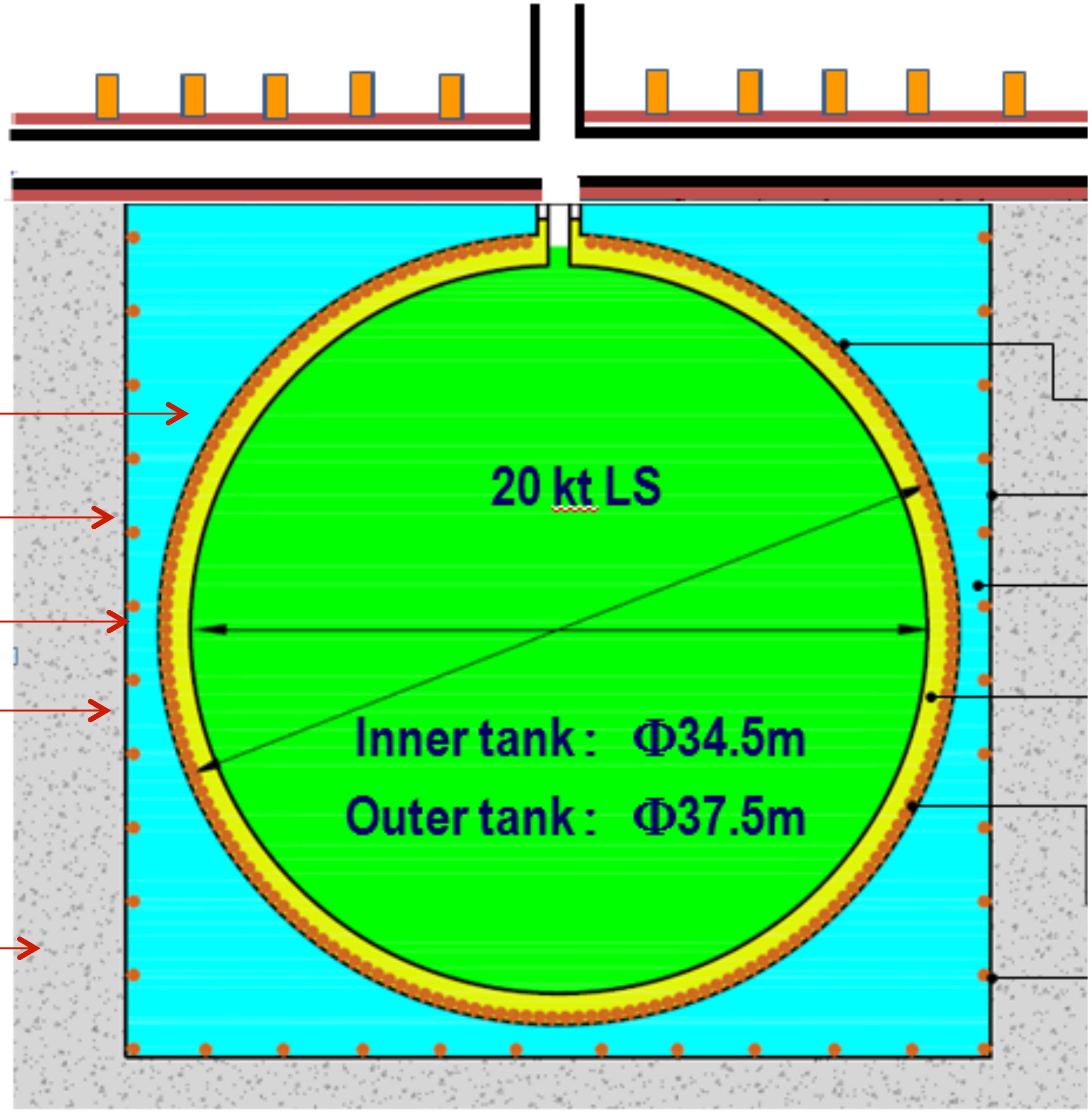




	R5912	R5912 -100	MCP -PMT
QE@410nm	25%	35%	25%
Rise time	3 ns	3.4ns	5ns
SPE Amp.	17mV	18mV	17mV
P/V of SPE	>2.5	>2.5	`2
TTS	5.5ns	1.5 ns	3.5 ns

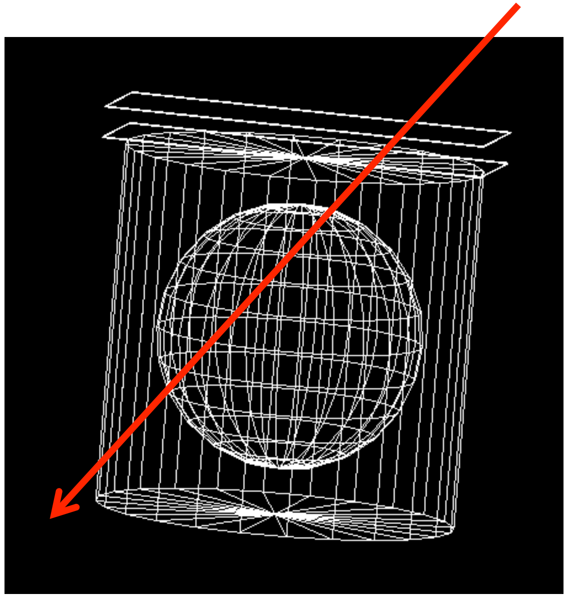
Muon VETO detector

- Top tracker
- Tracker support
- Water system
- Tyvek
- PMT support
- Water pool liner
- Earth magnetic shielding



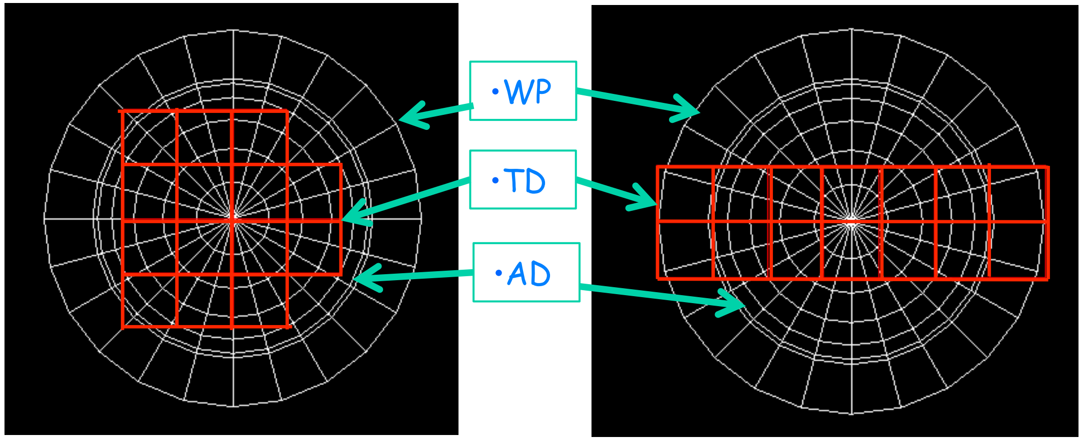
OPERA Target Tracker for the Top Tracker

- 56 x-y walls (6.7m×6.7m each)
- 14 TT stations, 4 walls each.
- each station is composed of 2 layers of 2 TT walls separated by 4 m distance.
- Distance of lowest and upper wall: 4 m
- Distance of lowest plane from water pool: 1 m.
- Different configurations (Middle, Rectangle, Around)
- Covered area is about 630m^2.

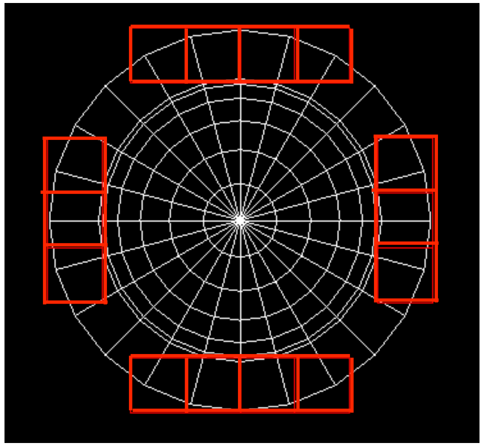


•4XY Middle (Mid)
•(3×4+2 modules)

•4XY Rectangle(Rtg)
•(2×7 modules)



•4XY Around("O")
•(2×4+2×3 modules)



Dismounting schedule

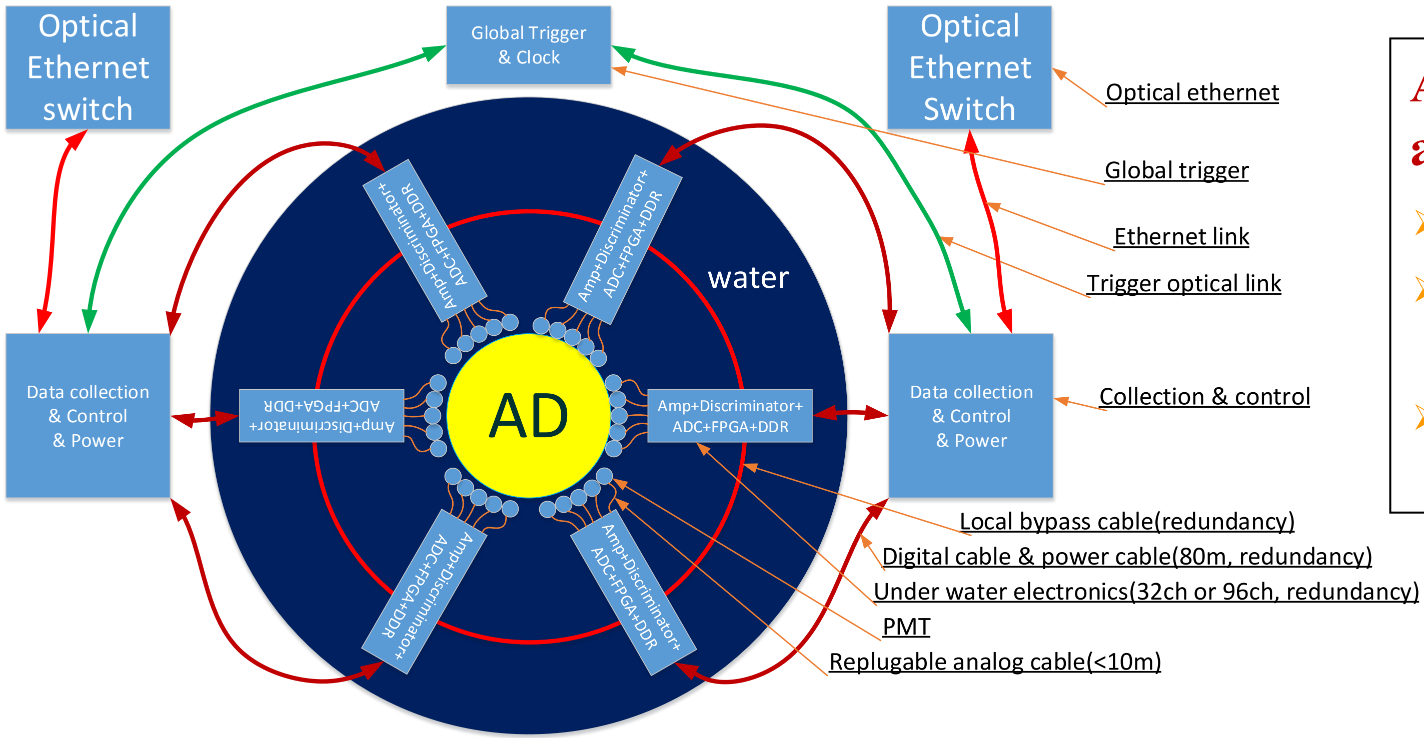
- Dismounting schedule:
  - mid-2015: first OPERA super module (31 TT walls, 248 modules)
  - beginning 2016: second OPERA super module (31 TT walls, 248 modules)
  - storage of all TT modules in Gran Sasso in containers up to the moment all dismounting is finished
  - send all TT containers (10) to Kaiping ~Spring 2016 if storage buildings already available
- Mounting in JUNO: ~2019

Readout Electronics and Trigger

- **Charge and timing info. from 1 GHz FADC**

Total No. channel	**20,000**
Event rate	**~ 50 KHz**
Charge precision	**1 – 100 PE: 0.1 – 1 PE; 100-4000PE: 1-40PE**
Noise	**0.1 PE**
Timing	**0-2us: ~ 100 ps**

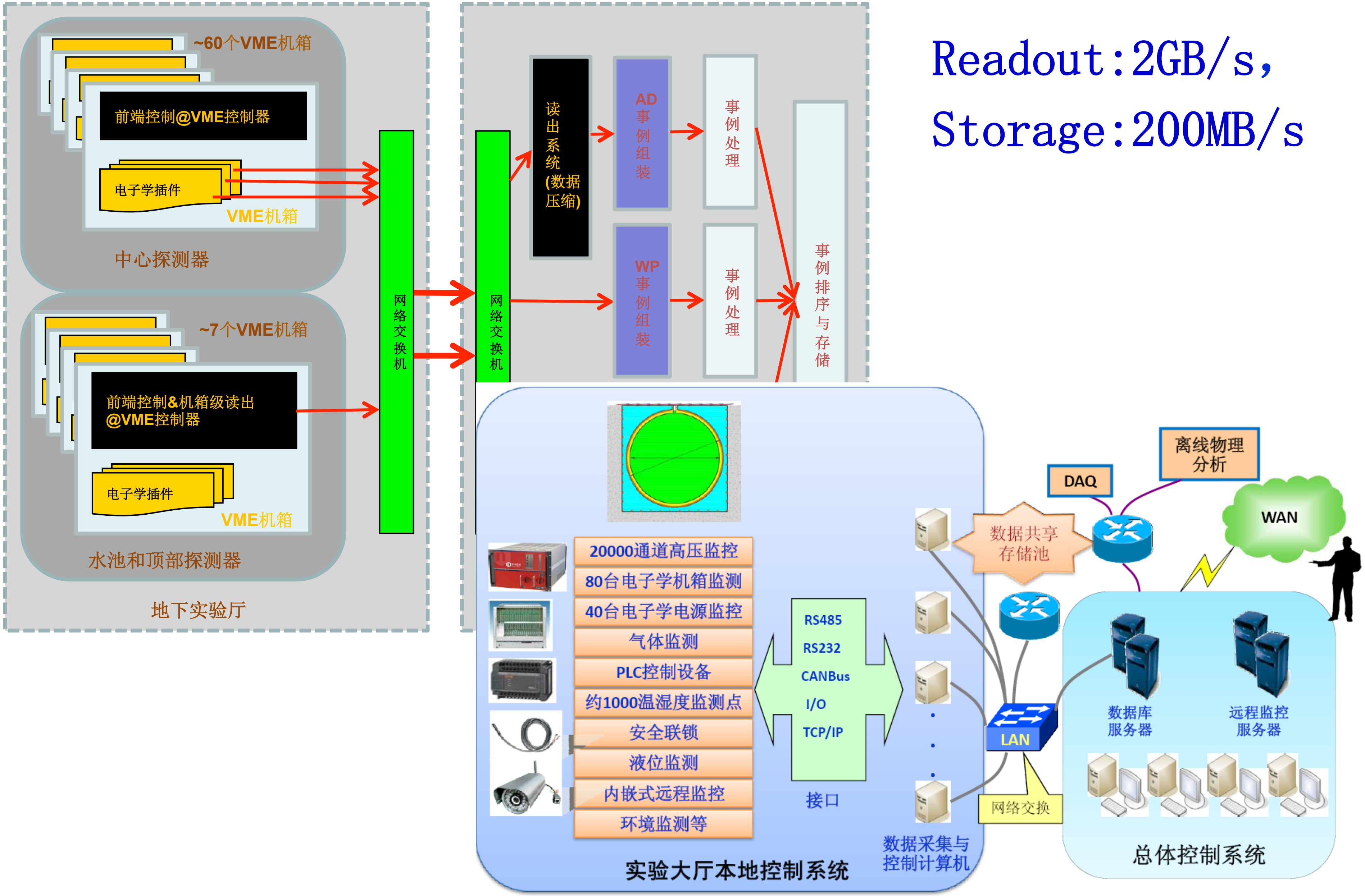
- **Main Choice to be made: in water or on surface**



An option to have a box in water:

- **~100 ch. per box**
- **Changeable in water**
- **Global trigger on surface**

DAQ and Detector Monitoring

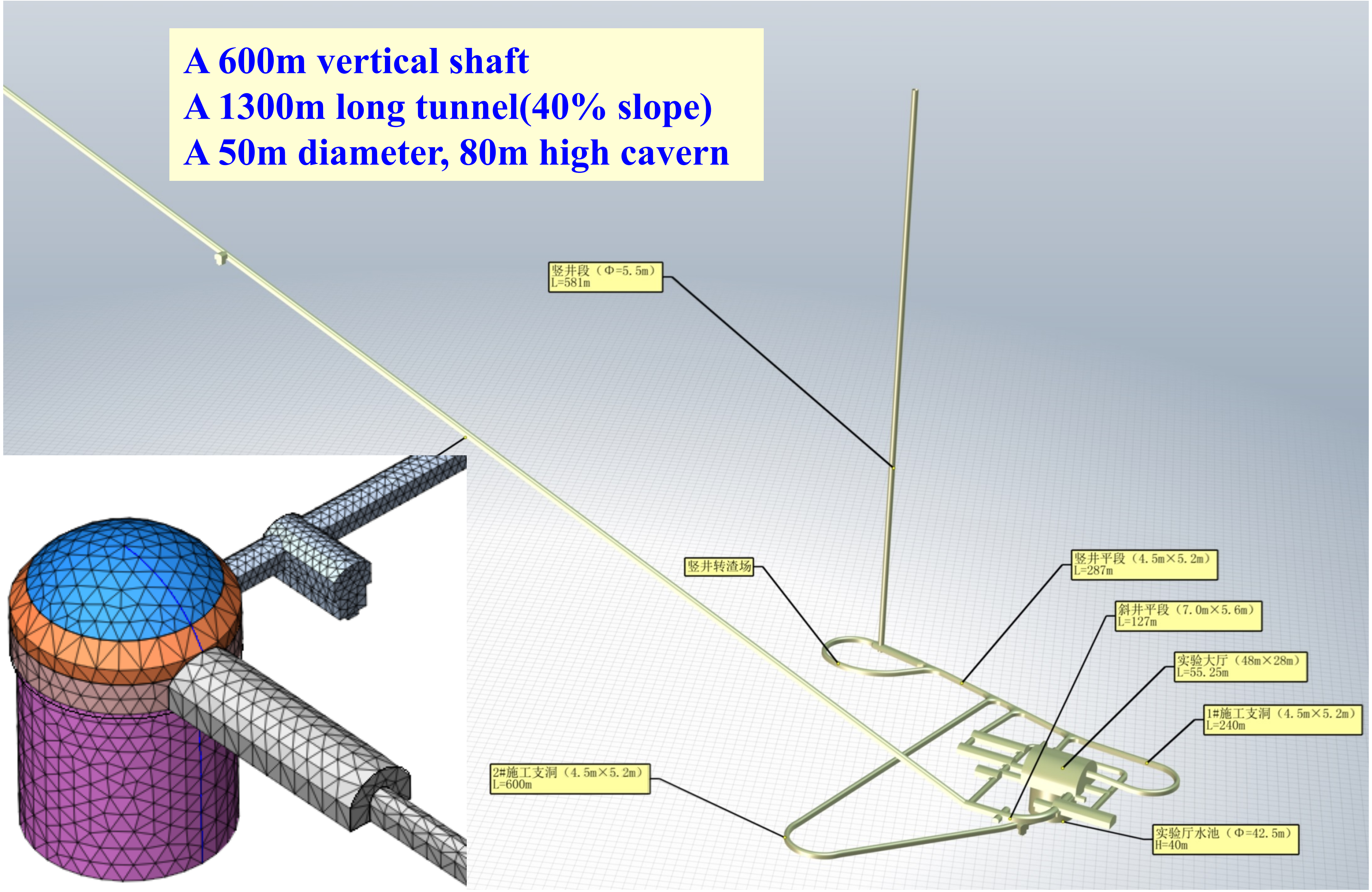


Readout:2GB/s,

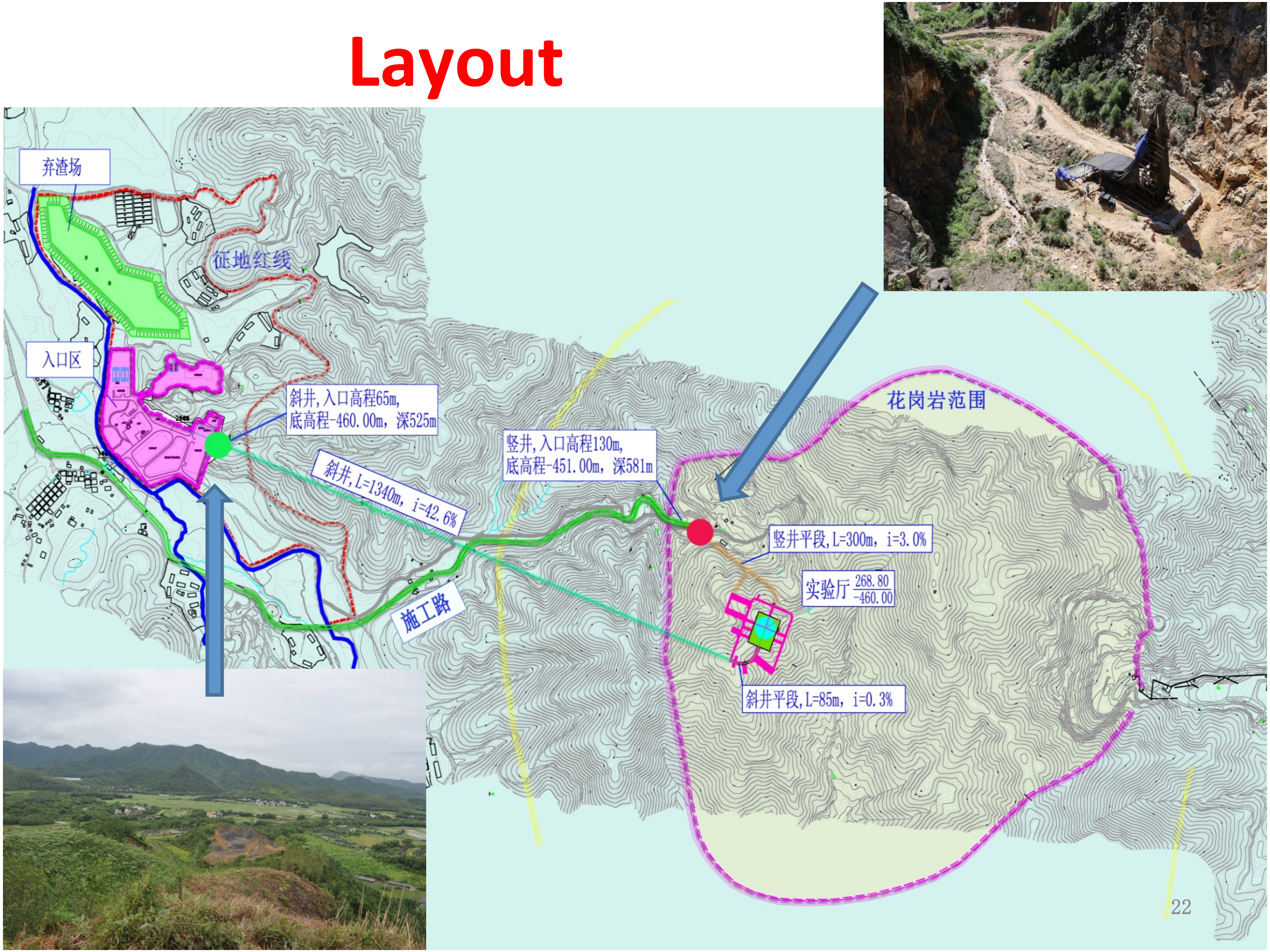
Storage:200MB/s

Civil Construction

A 600m vertical shaft
A 1300m long tunnel(40% slope)
A 50m diameter, 80m high cavern



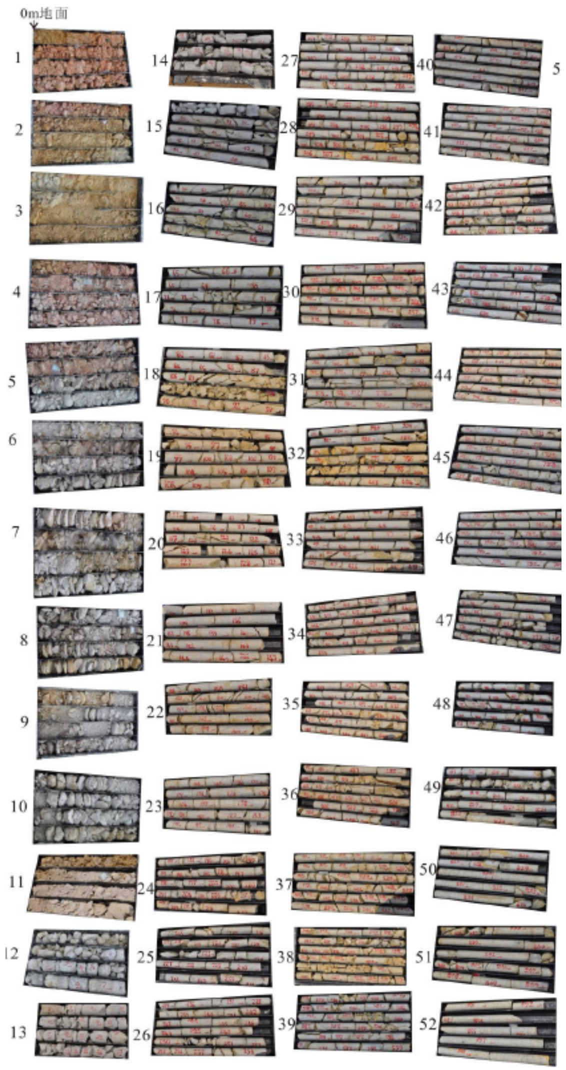
Layout



弃渣场
征地红线
入口区
斜井,入口高程65m,
底高程-460.00m，深525m
斜井,L=1340m，i=42.6%
竖井,入口高程130m,
底高程-451.00m，深581m
花岗岩范围
竖井平段,L=300m，i=3.0%
实验厅 268.80 -460.00
施工路
斜井平段,L=85m，i=0.3%

Current Status & Brief Schedule

- **Project approved by CAS for R&D and design**
- **Geological survey completed**
  - ⇨ Granite rock, tem. ~ 31 °C, little water
- **Engineering design underway, contract signed**
- **Land is acquired, civil construction approval underway**



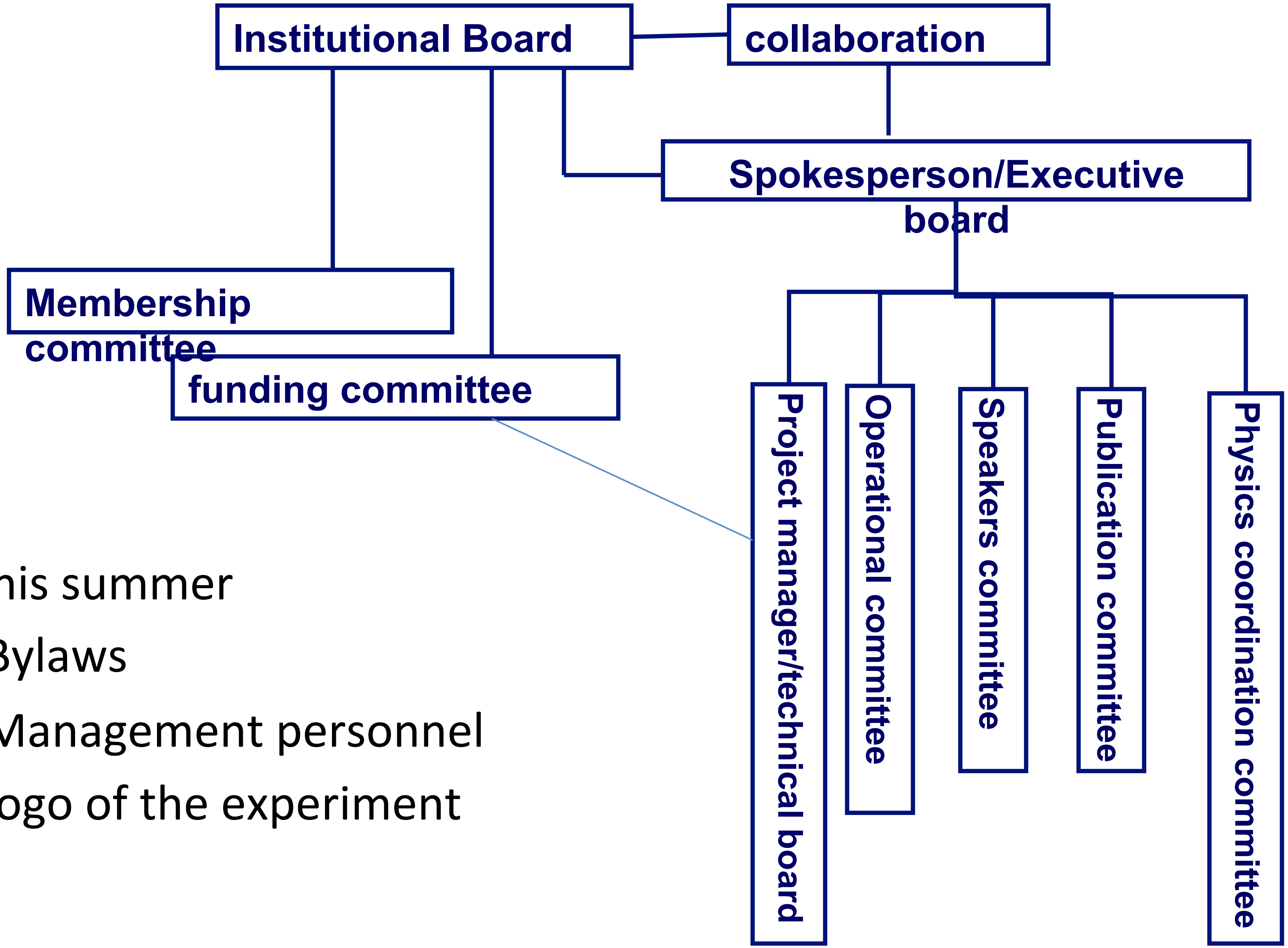
Schedule:

Civil preparation：2013-2014
Civil construction：2014-2017
Detector R&D：2013-2016
Detector component production：2016-2017
PMT production：2016-2019
Detector assembly & installation：2018-2019
Filling & data taking：2020

International collaboration

- Status of each country
  - Italy: committed
    - Milan, Frascati, Perugia, Padova… → Liquid Scintillator, PMT, …
  - Germany: almost committed
    - Munich, Aachen, Tubingen, … → Electronics, …
  - France: almost committed
    - Paris, Strasburg,… → VETO， electronics
  - Russia: almost committed
    - Dubna → PMT HV
  - US: waiting for P5
    - DYB + Hawaii, Washington, Maryland, … → calibration…
- Proto-collaboration since 2013, meeting every 6 months
- Formal collaboration this summer

Collaboration organization: to be approved



This summer

- Bylaws
- Management personnel
- logo of the experiment

Next plan

- By end of this year before the civil construction, we will have a major review in China to answer the question: “Can we start ?”
  - A yellow book of JUNO physics
  - A CDR of JUNO detector
- They are useful for everyone to get funding
- Task sharing by end of this year:
  - For funding estimate


Welcome to Kaiping

22/05/14